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Produced for: Cmdre Scott Bishop, Commander Canadian Fleet Atlantic

Scientific Letter

A trend analysis of sea day measures

Background

In October 2013 the MARLANT N02OR team of DRDC, Centre for Operational Research and Analysis (CORA) was asked by Commander Canadian Fleet Atlantic (COMCANFLTLANT) to collaborate with the Commanding Officer (CO) and Weapons Officer (WpnsO) from HMCS Charlottetown on a high-level analysis of the change – if any – in the scope and complexity of the fleet's operations over time. More concisely, they were asked to assess whether Canadian Fleet Atlantic is conducting the same intensity of effort at sea today compared to historical levels.

A fundamental issue is that the Royal Canadian Navy (RCN) uses the number of days at sea as the common metric to help quantify a ship's progression towards a particular level of readiness (see Ref. A), but counting these "sea days" alone may not relay enough information. For example, one day at sea for a Halifax-class frigate conducting a fisheries patrol (FISHPAT) is not equivalent to a day at sea conducting anti-submarine warfare (ASW) while in theatre; the latter requires more training, has higher inter-ship communication demands and typically involves co-ordination with assets other than the frigate itself (e.g., other ships and maritime helicopters). Thus, part of the analysis was to find ways to measure the intensity of sea days, coined as the sea day's "complexity" by COMCANFLTLANT. Particularly as the number of ships at sea is being reduced while the Halifax-class ships are going through mid-life refit, there is an interest in validating whether the fleet is still doing the same level of "core RCN" activities at sea as it has in the past.

Due to the relatively quick response requested by COMCANFLTLANT, the HMCS Charlottetown team and the MARLANT N02OR team assessed the information sources that were readily available and amenable to analysis. The approach taken was to examine the last 10 years of the CANFLTLANT's operational schedule (OPSKED), assign each day's activity to a category, derive a complexity value for that category, and finally analyze how or whether the total number of "complex" sea days have changed over time.

Data Generation

As a first step, each day's activity at sea recorded in the CANFLTLANT OPSKED[1] (used as a proxy for the whole RCN fleet) was placed into one of nine *exercise categories*:

[1] A consideration for a more thorough forward-looking analysis is that the activity that was scheduled is not necessarily that which was executed (i.e., if the ship was called away on an emergency or priority tasking). It was assessed by the team that this would have a relatively small effect on the overall results, and in any case should not introduce a bias to the year-over-year trend.

- “Joint Warrior”: Any exercise intended to enrich the Navy’s “battle” experience in a multinational task-group setting.
- “TGEX” (Task Group Exercise): An exercise intended to enrich the Navy’s “battle” experience in an RCN task group setting.
- “CJOC” (Canadian Joint Operations Command): Deployed operations of one or more RCN assets in an international theatre of operation. This category’s label stems from the fact that such operations are now under the command of CJOC; however, all similar deployments prior to 2011 under its predecessor organizations were filed under this category.
- “WUPS”: The required “work-ups” at sea required to bring a ship up to a certain level of readiness.
- “NANOOK”: Various domestic operations including OP NANOOK, in which the RCN participates with other government departments to improve coordination in responding to emergencies within national boundaries, and to exercise and defend Canada’s sovereignty.
- “CARRIBE”: Any days at sea conducting multi-national constabulary operations such as the drug interdiction operation OP CARRIBE.
- “FISHPAT”: Conducting fishery patrols in Canadian waters in support of Fisheries and Oceans Canada.
- “GLD” (Great Lake Deployments): Any days at sea conducting OP CONNECTION-like events such as the Great Lake Deployments which are part of the RCN’s outreach programme.
- “Other/ISE” (Independent Ship Exercises): The remaining activities at sea in the OPSKED which are attributable to e.g., harbour trials and sea trials.

Once the categories were defined, the HMCS Charlottetown team had four subject matter experts (SMEs) assign a series of complexity scores from 1 to 5 for each of the first eight exercise categories (see Annex A for the meaning of the scores). These scores were assigned for each warfare area (ASW, ASuW, AAW, FP, MIO[2]), as well as for “air detachment used” (binary assessment, rather than 1 to 5), for general “seamanship” activities, and for “ISE vs multi-ship.” For brevity, we will use *activity* to encompass the warfare areas along with “air detachment”, “seamanship” and “ISE vs multi-ship”. Sea days attributed to “Other/ISE” were not scored, and so have an effective score of 0.[3]

Methods

For each exercise category, MARLANT N02OR treated the individual SME scores as an indicative distribution of expected SME responses. For instance, in evaluating the MIO complexity of the TGEX activity, the four SME assessments were {3, 1, 2, 1}. Thus, 0% of SMEs gave a “0”, “4” or “5” rating, 50% gave a “1” rating, 25% gave a “2” rating and 25% gave a “3”. The distribution of possible totals for each exercise category was thence constructed by convolution of these four-point distributions.[4] In this way, it was easy to see the spread in possible totals for each exercise. Table 2 in Annex B summarizes the results of the individual SME assessments.

Using the data thus prepared, the first analysis method was to then create an overall per year “complex sea days” total, using each exercise category’s “complexity” score as a weight when totalling the number of sea days. For example, if 14 days in a given year were spent on “Joint Warrior”-type exercises, and that category had a complexity value of (say) 28, then its contribution to “complex sea days” for the year would be 28 x 14 = 392. A trend analysis was then conducted on these yearly complex sea days over a 10 year window.

[2] ASuW: anti-surface warfare, AAW: anti-air warfare, FP: force protection, MIO: maritime interdiction operations.
[3] This activity covers sea days not included in the other activity categories, and generally represents single ship operations. While “ISE vs. Multi-Ship” was used as a factor within each activity, there are purely ISE days which do not contribute to the generation of warfare skills (although they are necessary for the regeneration of the ship and crew).
[4] “Convolution” is the mathematical procedure used to construct the probability function of a variable from the probability functions of each independent factor that contributes to that variable (see page 811 of Ref. B).

Because there are known issues with weighted-sum schemes (Ref. C), a second method was employed. The convolution methods were first used to determine the most highly rated exercises on the complexity score, then, once this group was established, a trend analysis was conducted to see how the yearly sea days of just this group fluctuated over the same 10 year window.

Results

The spread in the estimated total score for each exercise is plotted in Figure 1. Two distinct groupings are visible: the “top 4” (blue) and the “bottom 4” (yellow-orange). These are called separate groups because within each group the spread in categorical exercise scores overlap, but no score spread in one group overlaps with a score spread of the other. For example, the “CJOC” curve (lightest blue) could have a complexity score of anywhere between 18 and 28, with an mean value of 23 and sample standard deviation of 2 (see Table 3 in Annex B), whereas the “TGEX” curve (light blue) could have a complexity score of anywhere between 20 and 31, with an mean and standard deviation of 25 ± 2. One may note that the spread in both “CJOC” and “TGEX” scores spread over each other and the other two “Top 4” exercises, but never over the “Bottom 4” exercises (CARRIBE, NANOOK, FISHPAT, GLD).

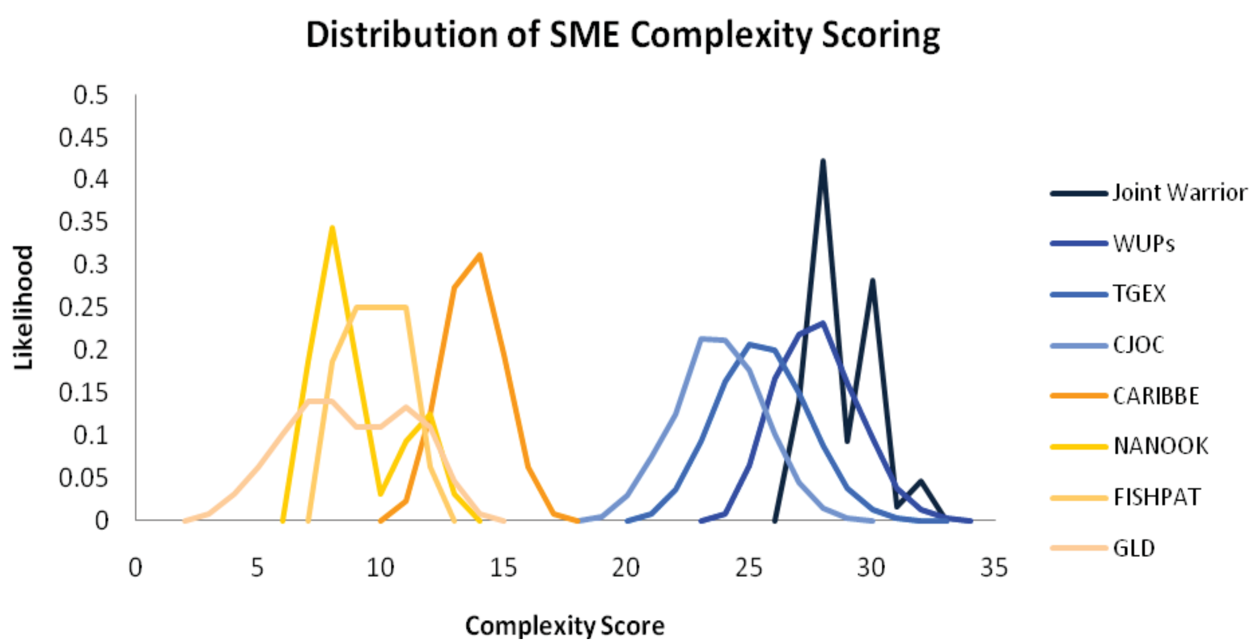

Figure 1: *Statistical Summary of SME Assessments.*

The average activity-to-exercise score (with standard deviation) is summarized in Table 3 of Annex B, all values being rounded to the nearest integer. For the “Total” column, the average and standard deviation are derived from the distributions displayed in Figure 1, with the final values being rounded to the nearest integer.

Taking the “Total” averages found in Table 3 in Annex B and multiplying them by the number of sea days for the corresponding exercise category in each fiscal year and adding those numbers, we calculate the total number of “complex sea days” per year, as shown in Figure 2, both in absolute scale (0 to 12,384 complex sea days) and relative to the maximum (FY 08-09 values).

The error bars represent the variability carried through using the standard deviations found in Table 3 of Annex B.

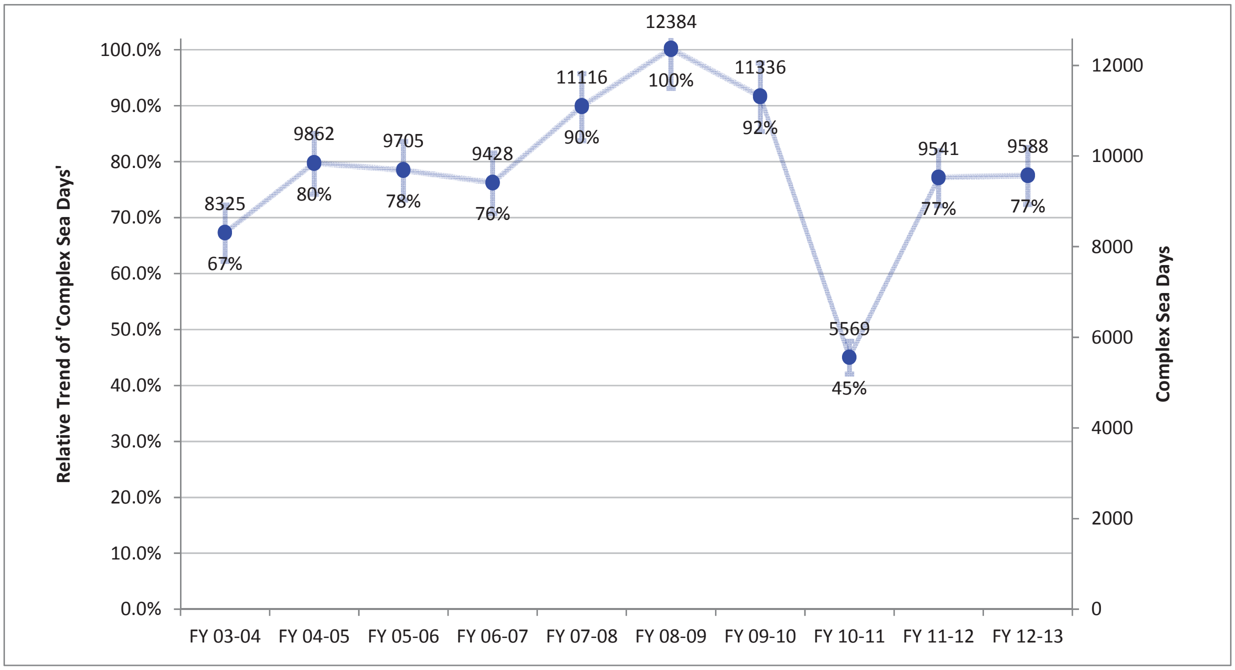

Figure 2: *Complex Sea Day Trend.*

The alternative method proposed above can then be compared to the first. Breaking the categorical exercises into the “Top 4” and “Bottom 4” and looking simply at the number of sea days falling into the “Top 4” per year, we arrive at the plot in Figure 3. Here we see an analogous trend line as that found in Figure 2. Because the total number of sea days varies from year to year, much of the trend for the “Top 4” can be explained by the overall yearly variability. To better show this effect, Figure 4 normalizes each fiscal year’s data to that year’s total sea days; as a result, it is easy to see what percentage of each year’s total sea days is consumed by each of the exercise categories. By normalizing to total sea days per year, one loses the total sea days per year information, and so we include it in Figure 4 as a fraction of the sea days consumed in FY 08-09 (829 days, the maximum over the 10 year span).

Finally, Figure 5 presents the total sea days, “complex sea days” and “Top 4” sea days, all normalized to FY 08-09 values in order to compare the trend lines. Note that the “complex sea days” is reproduced from Figure 2, the “Top 4” sea day trend is the one found in Figure 3, whereas the “sea days” trend can be found in Figure 4. The “Top 4” sea day trend and the “complex sea day” trend have nearly the same characteristics.

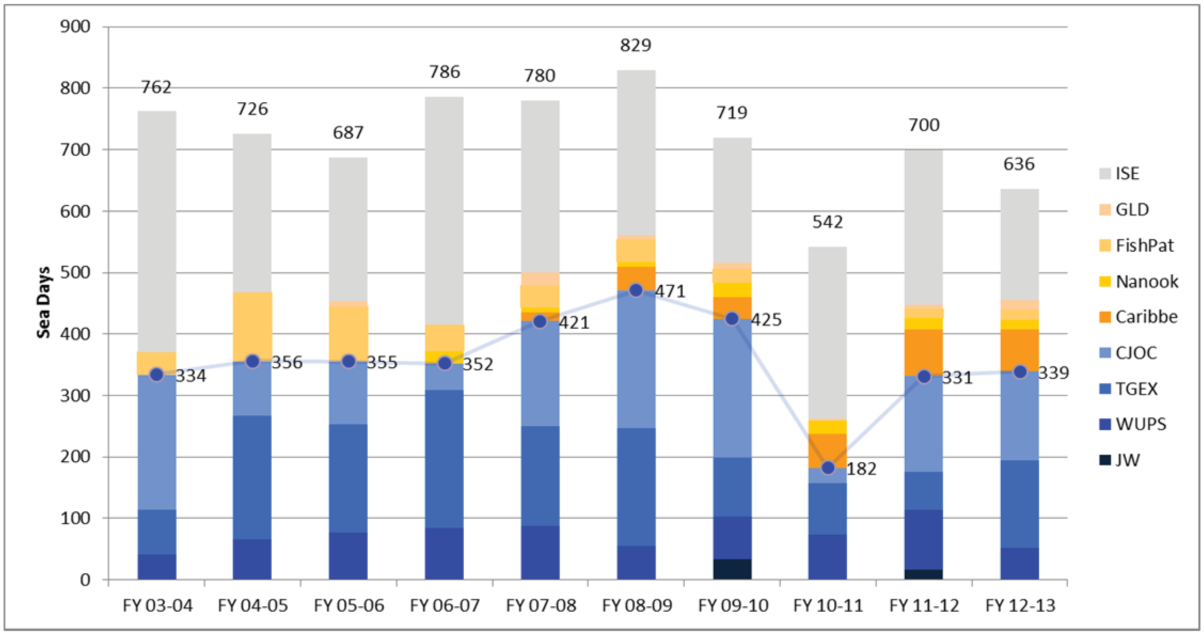

Figure 3: *Sea Days Per Exercise, with "Top 4" Trend.*

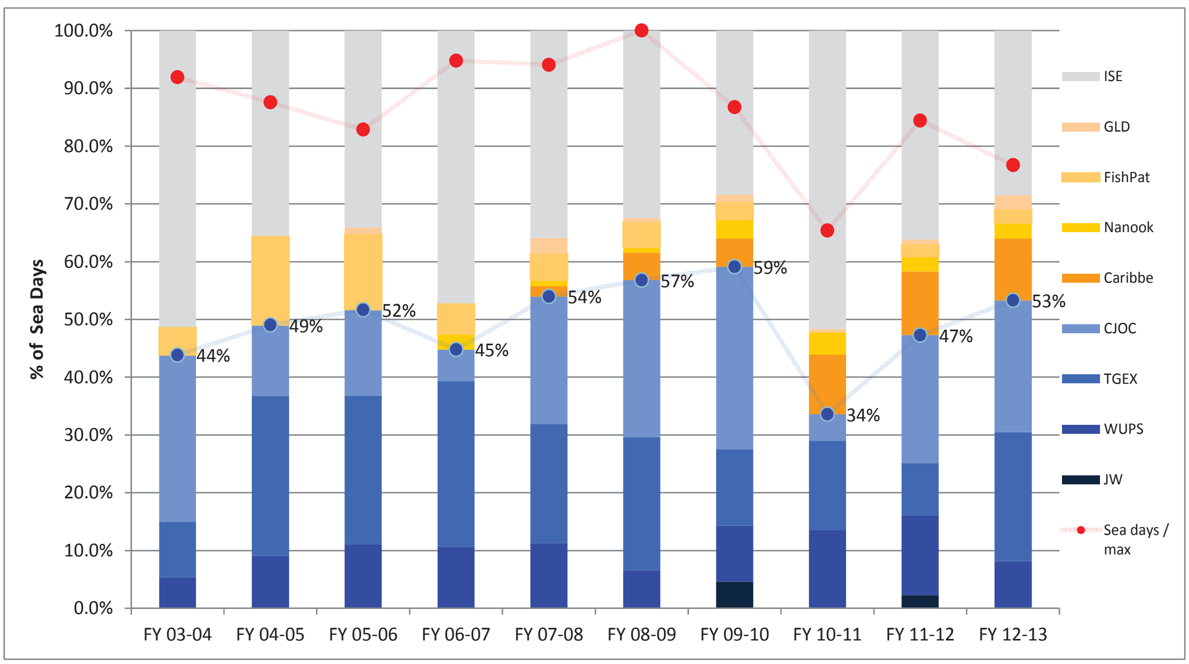

Figure 4: *Relative Sea Days per Exercise, with "Top 4" Trend and Relative Sea Day Trend.*

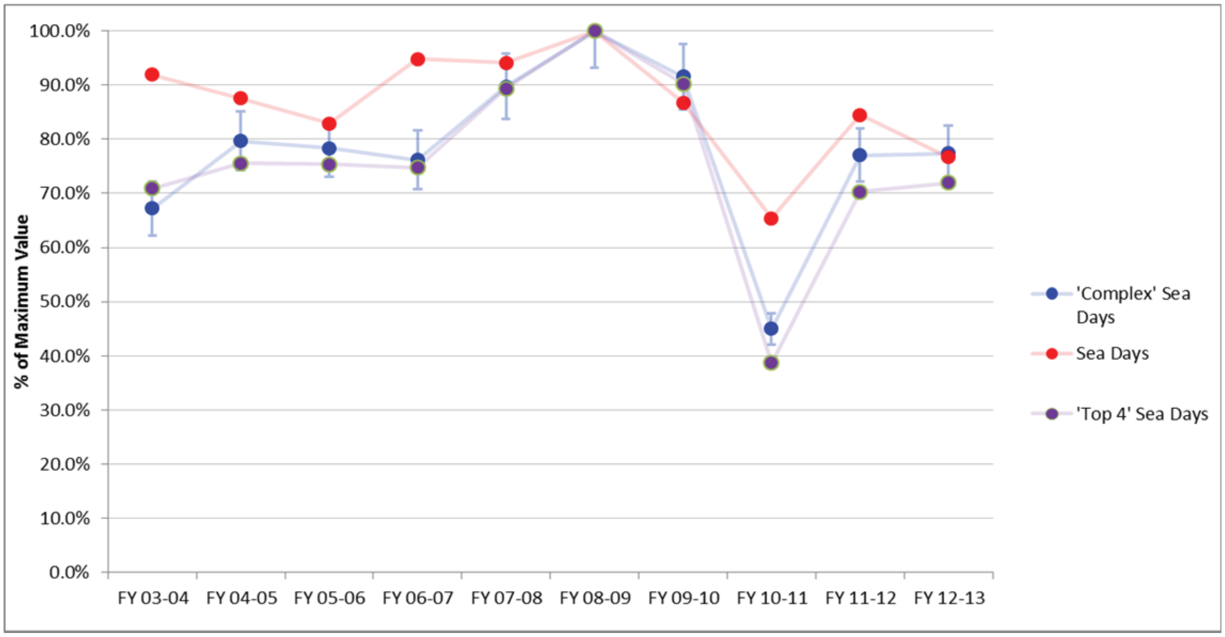

Figure 5: *Comparison of three "Sea Day" Measures.*

Conclusion

This analysis was conducted out of the need for COMCANFLTLANT to assess whether CANFLTLANT is doing the same level of “core RCN” activities at sea as it has in the past, especially in the context of its ships’ mid-life refits. A key component is to provide sense of the relative “intensity” of sea days, in the sense of whether a fleet is exercising its key functions as a warfare fleet. The first proposed method was a weighted sum of sea days where the weighting comes from subject matter expertise to assess how important an exercise category is in terms of core RCN capabilities.

MARLANT N02OR’s reservation to a weighted-sum scheme is that it is well known to the operational research community that such methods can in general lead to spurious results (see Ref. C). The method of combining SME assessments to determine how “strong” an exercise category is in terms of core RCN activities is valid, but to proceed to treat those ranks as numerical weights requires caution.

The analysis here presented both the trend of this “complex sea day” measure, as well as the trend in the unweighted total number of sea days spent on only the “Top 4” most complex activities. The analysis shows that the two methods are indeed comparable here and that the weighted – sum method provided consistent results in this case. MARLANT N02OR recommends that Figure 3 be used by COMCANFLTLANT since it provides a more rich set of data (# of sea days per exercise, cumulative sea days of the “Top 4” as well as the total sea days per year) than the first method. Although Figure 2 depicts a measure that is easy to explain, the absolute numbers (e.g., 12,384 complex sea days) do not have any physical meaning, and can change dramatically in magnitude by choosing different SME scales (e.g., 0 to 100). On the other hand, the numbers in Figure 3 are straightforward in their interpretation; the sea days have physical meaning and the colour code clearly separates the categories into bins of “warfighting capability” vs “constabulary and presence”. Although the activities belonging to the second group are important from a Government of Canada point of view, those in the first group are a vital concern to a commander in order to ensure the CANFLTLANT is a trained and

ready combat-capable force. As a companion to Figure 3, it should be noted that Figure 4 provides the fraction of sea days per year allocated to each categorical exercise.

The authors recommend that the notion of weighting a sea day based on a measure of intensity ought to be pursued further. The two methods explored here (complex sea day trend and “Top 4” exercise trend) yield similar results. However, given the arbitrariness of the scale used in any SME assessment, it would be useful to find a method of describing the intensity of a sea day in terms of physical parameters. MARLANT N02OR is currently investigating whether the required information sharing in different exercises would provide a useful intensity measure with physical meaning.

The trends depicted in Figures 2 and 3 indicate that the fleet’s “complex” days at sea are indeed comparable to those found 10 years ago, even though the total number of sea days per year are now fewer than before by about 100 for the fleet. There is a noticeable rise in complex sea days found from 2007-2010 and an interesting dip in 2010-2012, which occurs in a period where there is has been a decrease in deployed operations assigned by CJOC. However, the last few years have had complex sea days commensurate with that found in 2003-2006 timeframe, when RCN resources were being used intensively used for OP APOLLO.

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[A] CFCD 102(K), *Maritime Command Combat Readiness / Training Requirements*, B-GN-002-000/RQ-001.

[B] Arfken, G, 1985, *Mathematical Methods for Physicists, 3rd Ed.*, Academic Press Limited, London.

[C] Kaluzny, B., and Shaw, R.H.A.D., 2009, *Sensitivity analysis of additive weighted scoring methods: how to fool your friends (again)*, DRDC CORA Technical Report TR 2009-02.

Attachments

Annex A: Complexity Score Meanings

Annex B: Subject Matter Expert Assessments

Annex A: Complexity Score Meanings

In assessing each activity against a categorical exercise, each subject matter expert was asked to provide either a 5-point rating (in most cases) or 0/1-point rating (in the case of air detachments). To achieve better consistency across the experts, each rating was assigned a specific meaning, in order to increase the likelihood of, for example, everyone's rating of "3" having the same objective meaning. Note that the intermediate values are explicitly left unassigned to allow flexibility of SME assessment (that is, rather than assigning "2" a specific meaning, it is intentionally left unassigned to mean "somewhere between 1 and 3").

Table 1: *Meaning the SME Assessment Scores.*

Anti-Submarine Warfare (ASW)	*1 - Units participate in ASW tracking with all avail sensors / maneuvering* *3 - Units participate in ASW tracking and air assets in multi-ship environment / maneuvering* *5 - Units participate with live sub-surface and air assets in multi-ship environment*
Anti-Surface Warfare (ASuW)	*1 - Units participate in ASuW tracking* *3 - Units participate in ASuW tracking in multi-ship environment with basic SURFIREX serials* *5 - Units participate in ASuW tracking in multi-ship environment with air assets with up to intermediate/advanced SURFIREX serials*
Anti-Air Warfare (AAW)	*1 - Units participate in AAW tracking* *3 - Units participate in AAW tracking in multi-ship environment with GUNEX serials* *5 - Units participate in AAW tracking in multi-ship environment with air assets with GUNEX serials*
Force Protection (FP)	*1 - FP entrance/exit harbour foreign port low-threat environment* *3 - FP entrance/exit harbour foreign port low- threat environment with increased frequency* *5 - FP entrance/exit harbour foreign port, with increased frequency in high-threat environment*
Maritime Interdiction Operations	*1 - Units conduct tracking and hailing in simulated environment* *3 - Units conduct tracking, hailing, boarding and follow on reporting real world vessels of interest in low threat environment* *5 - Units conduct tracking, hailing, boarding and follow on reporting real world vessels of interest in a high threat environment*
Seamanship	*1 - Basic at-sea navigation and seamanship evolutions* *3 - Intermediate navigation, station keeping, task group maneuvering, resupply alongside, increased SS duty activities* *5 - Advanced navigation, advanced seamanship evolutions (TOWEX)*
Air Detachment	*0 – No detachment used in exercise* *1 – Detachment used in exercise*
Independent Ship Exercise (ISE) vs Multi-ship	*1 – ISE* *3 – Multi-ship, low tempo* *5 – Multi-ship, high tempo*

Annex B: Subject Matter Expert Assessments

Table 2 provides the individual assessments of each “activity” against the categorical exercise (due to its late edition and time constraints, “ISE vs Multi-ship” was assessed by one SME only). To help elucidate the results, consider the four assessments of maritime interdiction operations “MIO” against CARRIBE-type exercises (“3,2,3,4”). Here one can see that two SMEs asserted that MIO scored “3” against CARRIBE (that is, “Units conduct tracking, hailing, boarding and follow on reporting real world vessels of interest in low threat environment”), whereas one scored “2” (somewhere between “1” and “3”, the former corresponding to “Units conduct tracking and hailing in simulated environment”) and the other scored “4” (somewhere between “3” and “5”, the latter corresponding to “Units conduct tracking, hailing, boarding and follow on reporting real world vessels of interest in a high threat environment”).

Table 2: *Raw SME Evaluations.*

	ASW	ASuW	AAW	FP	MIO	Air Det	Seaman-ship	ISE vs Multi-ship
Joint Warrior	5, 5, 5, 5	5, 5, 5, 5	5, 5, 5, 5	1, 2, 2, 2	1, 1, 3, 1	1, 1, 1, 1	3, 5, 3, 3	5
TGEX	5, 3, 4, 3	5, 4, 4, 5	5, 3, 4, 5	1, 2, 3, 1	3, 1, 2, 1	1, 1, 1, 2	4, 3, 3, 3	4
GLD	1, 0, 1, 0	1, 0, 1, 0	1, 0, 1, 0	3, 1, 3, 4	1, 0, 1, 0	0, 0, 0, 0	1, 1, 5, 5	1
NANOOK	1, 1, 1, 1	1, 1, 1, 1	1, 1, 1, 1	1, 1, 1, 2	1, 0, 1, 0	0, 0, 0, 0	1, 1, 2, 5	1
CARIBBE	1, 2, 1, 1	1, 1, 1, 1	1, 1, 1, 1	3, 2, 2, 3	3, 2, 3, 4	0, 0, 0, 0	1, 2, 2, 3	2
FISHPAT	1, 1, 1, 1	1, 1, 1, 1	1, 1, 1, 1	1, 1, 1, 2	1, 2, 3, 4	0, 0, 0, 0	1, 1, 1, 1	1
CJOC	2, 2, 3, 2	2, 3, 3, 3	2, 4, 3, 2	2, 4, 4, 5	4, 5, 5, 5	1, 1, 1, 1	3, 3, 5, 3	2
WUPs	3, 3, 5, 3	3, 3, 5, 4	3, 3, 5, 4	3, 3, 4, 3	3, 3, 3, 2	1, 1, 1, 1	5, 4, 5, 5	4

Table 3 summarizes the mean scores and the standard deviation, statistically derived from Table 2. The four scores in each cell in Table 2 (e.g., {3, 2, 3, 4}) were used to estimate the likelihood of each score in that cell, and those score likelihoods were convolved across each exercise category. The mean and standard deviation in the “Total” column of Table 3 are from this convolved dataset.

Table 3: *Mean Scores between SME Assessments (including standard deviation).*

	ASW	ASuW	AAW	FP	MIO	Air Det	Seaman-ship	ISE / Multi-ship	Total
Joint Warrior	5 ± 0	5 ± 0	5 ± 0	2 ± 1	2 ± 1	1 ± 0	4 ± 1	5	28 ± 1
TGEX	4 ± 1	5 ± 1	4 ± 1	2 ± 1	2 ± 1	1 ± 1	3 ± 1	4	25 ± 2
GLD	1 ± 1	1 ± 1	1 ± 1	3 ± 1	1 ± 1	0 ± 0	3 ± 2	1	9 ± 2
NANOOK	1 ± 0	1 ± 0	1 ± 0	1 ± 1	1 ± 1	0 ± 0	2 ± 2	1	8 ± 2
CARIBBE	1 ± 1	1 ± 0	1 ± 0	3 ± 1	3 ± 1	0 ± 0	2 ± 1	2	13 ± 1
FISHPAT	1 ± 0	1 ± 0	1 ± 0	1 ± 1	3 ± 1	0 ± 0	1 ± 0	1	9 ± 1
CJOC	2 ± 1	3 ± 1	3 ± 1	4 ± 1	5 ± 1	1 ± 0	4 ± 1	2	23 ± 2
WUPS	4 ± 1	4 ± 1	4 ± 1	3 ± 1	3 ± 1	1 ± 0	5 ± 1	4	27 ± 2